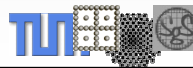


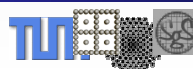
Interpreting the Results: Visualization

- visual/graphical/optical representation of large sets of data:
 - data from experiments or measurements: satellite images, tomography in medicine, microscopy, ...
 - data from simulations:
 - with resolution of time: fluid mechanics, structural mechanics, quantum physics, ...
 - without spatial resolution: vehicle dynamics, optimal control, ...
 - often the only chance to tackle a fast interpretation
 - methods stem from
 - image processing
 - computer graphics
 - virtual and augmented reality
 - ...



Methods of Image Processing

- image: array of 2D/3D discrete greyscale/colour data
- geometric processing:
 - changes of shapes
 - depend on pixels' position, not on their values
 - examples: zooming, rotation, ...
- point-to-point processing:
 - local changes of pixel values
 - depend on current values, but neither on geometry nor on neighbours' values
 - examples: addition of constants, contrast stretching, false colours, exponential transformations
- local-to-point processing:
 - local changes of pixels' values due to environment

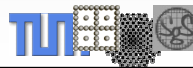


Methods of Image Processing 2

- local-to-point processing (continued):
 - examples: local weighted averaging (convolution, smoothing), local rank operators (median, sorting), segmentation (thresholds, filtering), edge detection, feature extraction, ...
- ensemble processing:
 - comparison of different images of the same scene
 - examples: detection of motion (military), difference images (medicine, monitoring agricultural activities or vegetation)
- domain processing:
 - complicated modifications of pixel values due to both local and global information
 - examples: Fourier or cosine transform (JPEG), wavelet transform, tomography (CT, NMR, ...)



Introduction to Scientific Computing
Lesson 13: Visualization



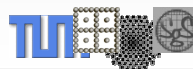
Slide 3

Aspects of Computer Graphics

- visualization is based on methods from graphics:
 - crash simulation: representation of cars and the whole scene, perspective view, ...
 - illumination for increasing realism
 - visualizing weather forecast (virtual flights): clouds, fog, ...
 - virtual reality and augmented reality techniques
- geometric modelling:
 - representing 3D objects
- graphical representation / rendering:
 - perspective
 - illumination
 - shading
- stereoscopy (cf. VR)



Introduction to Scientific Computing
Lesson 13: Visualization



Slide 4

Simulation Data Resolved in Time & Space

- given: result (data set) of some numerical simulation

$$f : \mathbb{R}^d \supset \Omega \rightarrow \mathbb{R}^m, \quad m \in \mathbb{N}$$

f: scalar or vector valued; clear for 2D, but 3D?

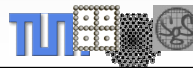
- different techniques for the visualization of 3D data:

- **lower-dimensional subdomains:**

- **(ortho-) slices:** the respective quantity is considered on some plane only (aligned with coordinate directions or not)
- **isosurfaces:** draw the surface on which the scalar f or one component of its components takes some prescribed value t:

$$I(c) = \{(x, y, z) \in \Omega : f(x, y, z) = c\}$$

interactive creation or modification (change of c, change in time) require efficient algorithms (marching cubes, e.g.)

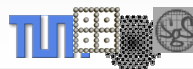


Visualizing Simulation Data 2

- visualization of 3D data (continued):

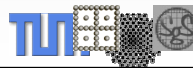
- **lower-dimensional subdomains (continued):**

- **streamlines:** for the visualization of vector fields ($m > 1$); curves with tangent always parallel to local vectors of the given vector field (velocities in CFD, e.g.)
- **particle tracing:** for the visualization of time-dependent vector fields; introduce a virtual particle somewhere and follow its path through the domain according to the vector field
- **streaklines:** for time-dependent vector fields, too; introduce a sequence of virtual particles somewhere and catch their positions at some point of time
- In the stationary case, all three methods lead to the same lines!
- furthermore: **streakbands**, **streaktubes** (allow to visualize additional quantities as well as rotation, e.g.)
- widespread: combinations of the above methods



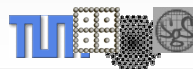
Visualizing Simulation Data 3

- visualization of 3D data (continued):
 - **colours:** use hue or intensity for expressing a scalar quantity
 - use intuition: red/blue for temperature
 - also possible: different colours for different quantities (temperature and concentration, e.g.; limit: about 5)
 - Take care of scale!
 - **use of graphical primitives:**
 - arrows, balls, ...
 - parameters: colour, size, distance (for speed)
 - **use of textures:**
 - for indicating material or other characteristics (type of soil)
 - **use of legends and annotations:**
 - very important: which scenario, which quantities, which scale
 - images without legends may be pretty, but not useful



Component Hierarchy of AVS/Express

- examples of commercial visualization tools:
 - AVS/Express
 - Explorer
- internal representation of data (hopefully able to profit from data structures used for the computations):
- example AVS:
 - **component hierarchy** (tree structure)
 - **field:** highest component, whole information
 - **mesh:** geometric description
 - grid: position of grid points
 - cells: neighbourhood relations, connectivity (edges, faces, elements, ...)
 - **data:** data of the grid (values of f), node data and cell data



Animation

- tremendous increase in data:
 - one image: some 4 MB, e.g. (1024x1280, 4 B per point)
 - video: some 25-30 images per second!
 - compression necessary (mpg, ...)
- pay attention:
 - smooth transitions (w.r.t. movement, colour, ...)
 - choice of scale:
 - stationary state: too restricted colour-scale at the beginning may suggest convergence even if there are still (small) oscillations
 - increasing differences: now, whole-spectrum colour-state at the beginning may prevent the actual values from being represented
 - if interpolation / inbetweening / frame techniques necessary: don't neglect (or even hide) disturbing details!

